Geochemical Investigation and Ore Genesis of Gold Mineralization in Kyathitmyaung Area, Kyaukkyi Township, Bago Region, Myanmar

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Abstract

This research mainly focuses on the geochemical investigation and ore genesis of gold mineralization in Kyathitmyaung area which is located in N-E of Kyaukkyi Township. The area lies between the complex structure of Sagaing Fault and Papun Fault, active faults. The composed rock unit is a Carboniferous sequence of Mergui Group that is dominated by deformed greenschist, phyllite, mudstone, quartzite, that exhibits a low grade greenschist facies metamorphism, and which is intruded by the granitic rocks of Mesozoic in age. Gold mineralization in Kyathitmyaung area is mainly hosted by phyllite. The gold mineralization occurred along shear zone. The presence of deformed gold-bearing quartz veins, and their relation with respect to the main mylonitic foliation and the shear zone. Formation of mylonite is by the complex structure and it seems from phyllite. This gave rise a suitable structural regime for vein-hosted gold mineralization. The ore minerals are pyrite, chalcopyrite, asenopyrite, galena, sphalertie and gold can occur as native in quartz fractures. The epigenetic gold mineralization resulted from metamorphic hydrothermal fluids circulating through major shear zones and associated structures during the late stages of orogeny. Metamorphic devolatilization and fluid flow is suggested for the genesis of the gold occurrences in both ductile and brittle structures. According to ore mineralogy, nature of mineralization, ore control and fluid inclusion study recommend that the type of gold mineralization at Kyathitmyaung area is consistent with the orogenic style and suggested as mesothermal type gold deposit.

Keywords: Mergui Group, Kyathitmyaung, mesothermal type, gold mineralization, ore genesis

Introduction

In Myanmar, both primary gold and secondary gold deposits occurred as the major country's resources. Recently, the Slate Belt on the western edge of the Shan-Thai Block is a major target for orogenic gold exploration in Myanmar. Kyathitmyaung gold prospect lies in the southern part of the Slate Belt and north eastern part of Kyaukkyi Township. This work mainly focuses on the identification of gold and associated ore minerals and their paragenesis, geochemical investigation and formation and origin of gold mineralization of the research area. Major gold occurrences and prospects in Myanmar are shown in figure 1.

Methodology

The research method mainly based on field investigation, laboratory works and suitable software. Measuring the geological data, collecting the representative rock and ore samples were done during the field work. Atomic Absorption Spectrometry (AAS), X-ray diffraction (XRD), Electron Disperse X-ray Fluorescence (ED-XRF), Fluid inclusion measurement were

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conducted as laboratory works. Thin and polish section were made for rock-forming and ore minerals identification.

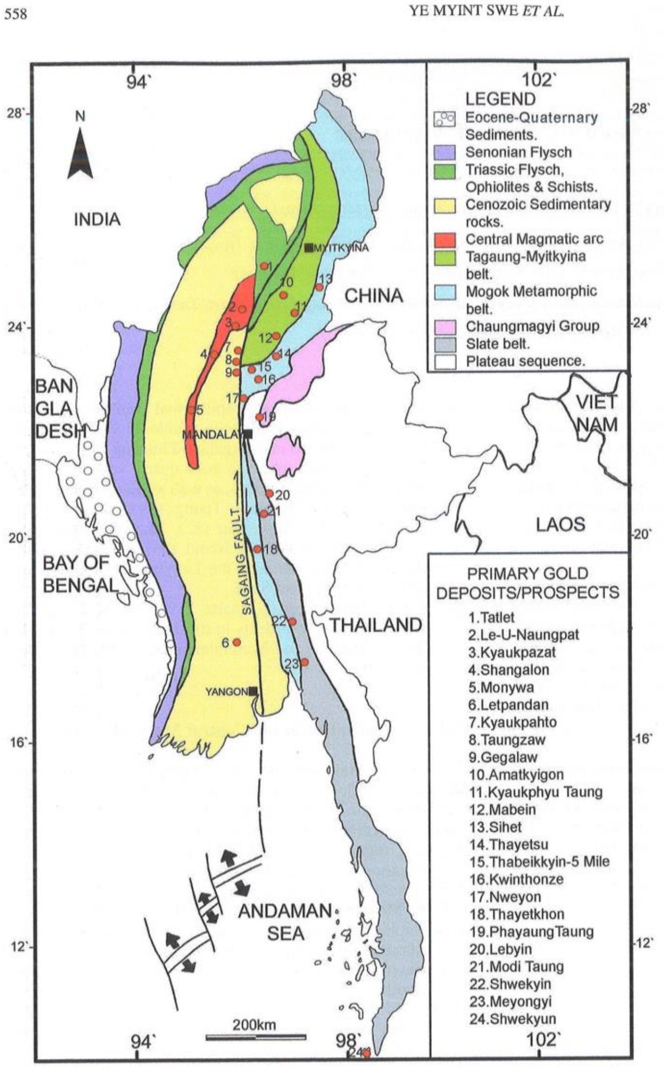

Figure 1. Major Tectonic belts and location of major gold deposits and prospects in Myanmar (compiled after Mitchell *et al*, 1999; Khin Zaw *et al*, 1999a,b, 2014,2015; Ye Myint Swe *et al*, 2004a,b)

Tectonic and Geologic Setting

Slate Belt hosted mesothermal lode gold deposits form in the subduction related accretionary or collisional terranes, and can form at all stages in the orogen evolution. They are also found in rocks ranging from Archean to Tertiary in age (Groves et al., 2003). The western part of Myanmar consists of the Indo- Burman Ranges, which are composed of sedimentary, metasedimentary, intrusive, and volcanic rocks that have been interpreted as an accretionary prism, including slivers of a dismembered ophiolite obducted above an east-dipping subduction zone (Curray et al., 2005; Chhibber, 1934; Hutchison, 1989). The Central basin is bounded on the east by the Sagaing fault, a major, right-lateral transform fault estimated to have accumulated 200–400 km of displacement since the Miocene (Curray et al., 2005; Mg Thein, 1973) The Sino-Burman Ranges and the Shan Plateau lie to the east of the Sagaing fault and consist of Precambrian and Paleozoic sedimentary and metamorphic rocks with affnities to the southern Asia and China plates (Betrand, 1983).

Most of the gold deposits are hosted by intrusive, volcanic, metamorphic and metasedimantary rocks. Kyathitmyaung gold prospecis one of the highest potential gold deposits in Bago Region which is located within the Slate Belt. The Kyathitmyaung area is composed of metasedimentary rocks of Mergui Group with the age of Carboniferous to Permian which is intruded by Mesozoic granitic rocks. The Mergui group consists of mudstone, slate, phyllite, schist and minor massive turbiditic greywacke and quartzite which underwent low grade regional metamorphism. The skarn and hornfels have developed at the contact zone between the granitic intrusion and metasedimentary rocks of Mergui Group.

Some sulfides are sparsely disseminated throughout the rock and are totally altered to limonite which can be seen as a good exposure. The granite is coarse-grained, massive and equigranular, although porphyritic and medium grained varieties are observed in places. Quartzofeldspathic and quartz veins are intruded into the granite. The Kyathitmyaung gold prospectlies between the Papun fault to the east and the major Sagaing Fault to the west. Papun fault is an old major sheared zone and reactivated since the eastward extrusion of continental blocks began from the India/Asia collision zone to the north in early Tertiary (Win Naing, 2006). The rock units in the Kyayhitmyaung gold deposit is weakly metamorphosed but strongly deformed and mylonitic textures of phyllite can be seen in brecciated shear zone. Figure 2 shows the district geological map of Shwegyin-Kyathitmyaung area.

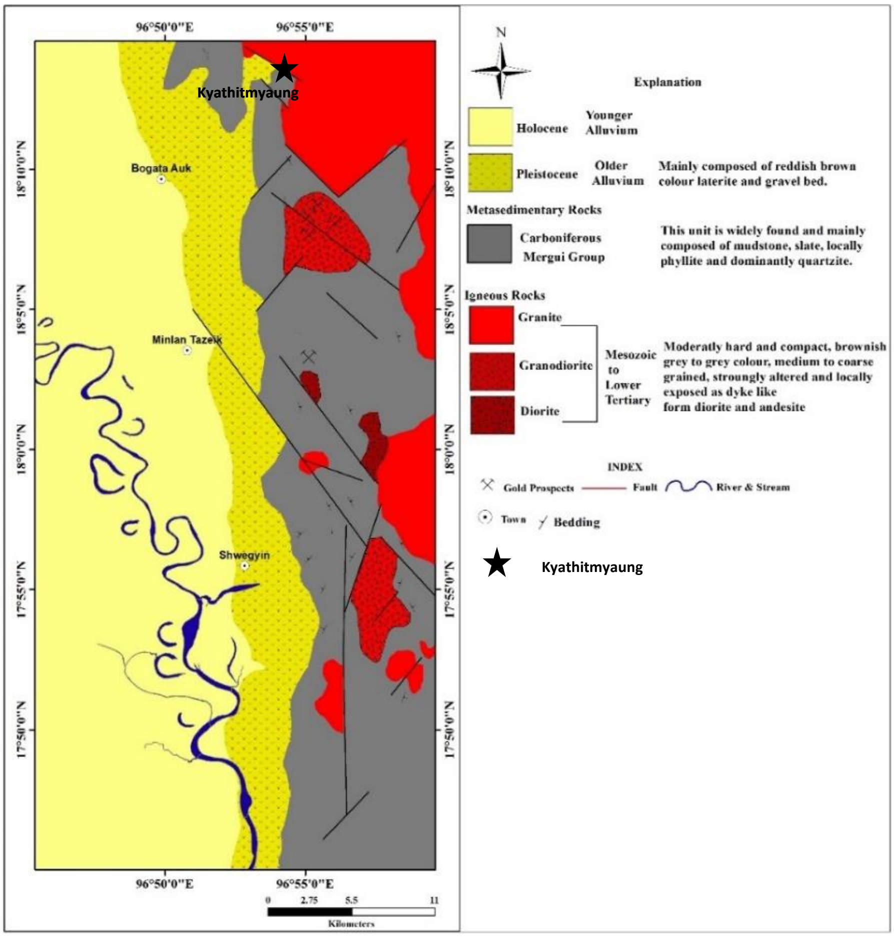

Figure 2. District geological map of Shwegyin-Kyathitmyaung area

Mineralization, Ore Mineralogy and Alteration

In the Kyathitmyaung area, gold-quartz veins are varying in the texture from massive laminated book and ribbon to breccia style are largely hosted by slate, phyllite, quartzite and minor greywacke of Mergui Group of Slate Belt. Gold occurs in veins which are accompanied by pyrite, arsenopyrite and minor base metal mineralization such as chalcopyrite, galena and sphalerite. Gangue minerals are quartz, sericite, clay and carbonate minerals as ankerite. Gold also occured as free grains in oxidized zone and inclusions and fracture fillings within pyrite which is closely associated with arsenopyrite. Figure 3 shows ore minerals and their texture under microscope and nature of ore mineralization. Gold-quartz veins with visible gold are similar to those shear-zone related gold deposits in Slate Belt elsewhere. Gold mineralization is largely confined to the alteration zone of metasedimentary rock of Mergui Group. The intense wall-rock alteration products are recognized as sericitization, chloritization, kaolinization and sulfidation. (Figure 4). The rock is intensively altered, fractured and brecciated.

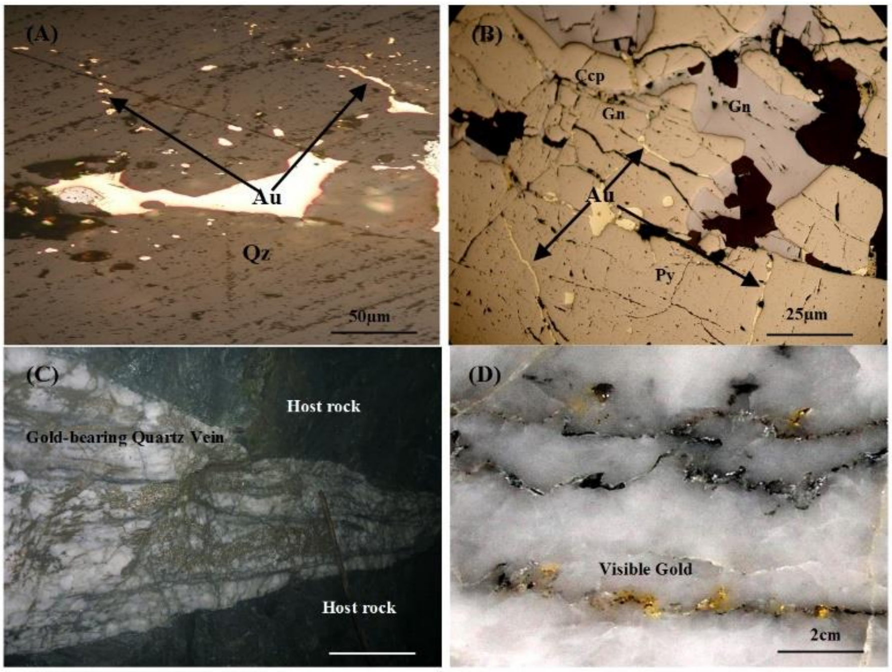

Figure 3. Photomicrographs of A. Native gold (Au) filling in quartz fracture, (B) Native gold (El) associated with pyrite (Py), chalcopyrite (Ccp) and galena (Gn) (Reflected Light), Photographs of (C) Nature of gold-bearing quartz vein and (D) Visible gold in quart fracture.

Paragenesis

According to the ore texture, ore mineral crystallizations have the two stages in the study area. The first stage is characterized by crystallization of coarse grained pyrite, galena and quartz. The second stage crystallization minerals are chalcopyrite, arsenopyrite and sphalerite because of the interpretation by polish-section, chalcopyrite, arsenopyrite and sphalerite are overgrown with the coarse grained pyrite and quartz. Gold is strongly associated in the second stage crystallization and deposited into the quartz fracture and pyrite. Paragenetic diagram of the research area is shown in figure (4).

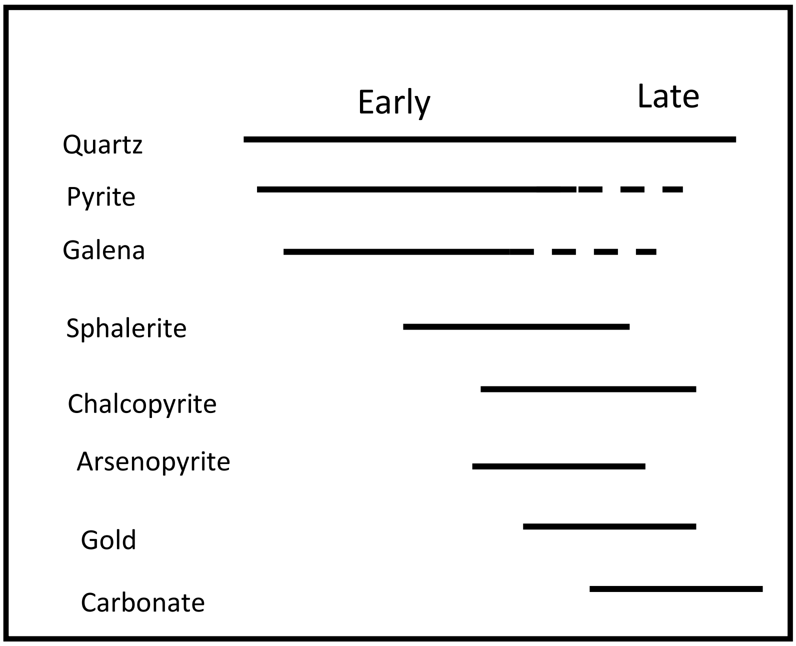

Figure 4. Paragenetic diagram of the gangue and ore minerals

Geochemical Investigation

Atomic Absorption Spectrometry (AAS)

Sample No.	Au	As	Ag	Cu	Pb	Zn	Fe
KTM-001	0.029	0.009	0.009	150	175	90	3750
KTM-002	0.009	0.004	0.012	145	150	105	3850
KTM-003	0.017	0.012	0.008	140	170	110	3500
KTM-004	1.214	0.027	0.007	148	190	95	3450
KTM-005	3.423	0.018	0.015	130	145	98	3700
KTM-006	0.018	0.008	0.007	125	135	125	3750
KTM-007	0.015	0.006	0.004	135	170	110	3650
KTM-008	1.147	0.017	0.012	140	150	115	3850
KTM-009	0.009	0.004	0.003	145	160	118	3900
KTM-010	2.014	0.003	0.002	130	175	125	3450
KTM-011	0.017	0.007	0.005	135	110	120	3350
KTM-012	0.016	0.008	0.006	130	165	115	3500
KTM-013	2.014	0.007	0.004	125	145	105	3550
KTM-014	0.019	0.008	0.005	325	210	110	3890

X-ray Diffraction (XRD Analysis)

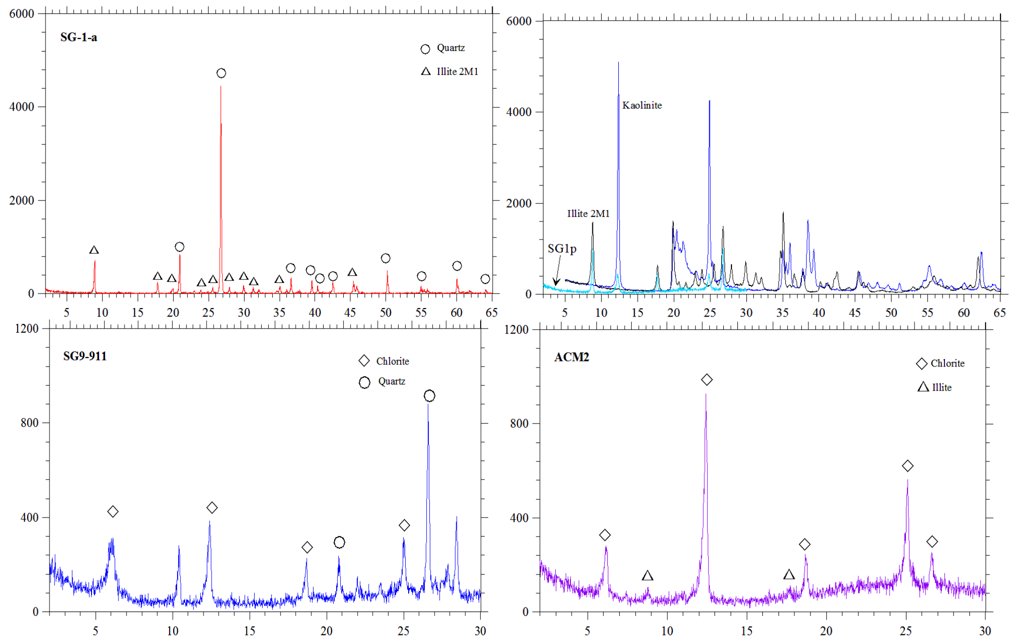

Figure 5. XRD results of alteration minerals.

X-ray Fluorescence (XRF)

To know the petrogenesis of research area, the geochemical result were conducted by the X- ray Fluorescence analysis. The representative samples were collected from the four igneous rocks types of the study area. X- ray fluorescence (XRF) is one of the most widely used instrumental methods for analyzing rock samples for major elements and selected trace elements. Weight percent (ppm) of major oxide is shown in table (1). The values of major and trace elements were interpreted by the Petro Graph and GCD kit software.

Weight percent (ppm) of major and trace elements were plotted the feldspar triangle of (O'connor 1965), TAS (middlemost 1944) diagram, TAS (cox etal 1979) diagram, shank, molar triangles, Peccerillo and Taylor diagram, Miyashiyo and AFM plot Irvine and Baragar (1971) triangle. According to the normative Ab – Or - An diagram, plutonic and volcanic rocks of the study area were filling the acid to intermediate granitic field by feldspar triangle of O' Connor (1965). Generally, igneous rocks are lying between acid to intermediate composition. Chemical classification of igneous in the TAS (total alkalies versus silica) diagram (after Cox et al. 1979). The dividing line between alkalic and sub- alkali magma series is chosen from (Mayashiro, 1978). The felsic and mafic minerals composition also indicate that these igneous samples range from granite, granodiorite, diorite, grabbro, andesite and rhyolite. Diagram of A/CNK-A/NK plot (Shand 1943) igneous samples are belonging to the metaluminus field. The diagram of SiO_2 – K_2O plot (Peccerillo and Taylor 1976) was sited at the shoshonite series. SiO_2- FeO_t/ MgO (Miyashiro 1974) diagram is filling the five analysis samples is Tholeiite series and six analysis samples is calc- alkaline series. AFM plot Irvine and Baragar (1971) is filled the calc- alkaline and Tholeiite series. According to the petrochemical analysis diagram, igneous rocks of the research area have three main type of magma series. They are calc-alkaline, shoshonite and tholeiite series. A magma series is a evolution of a mafic magma, which is high in magnesium and iron oxide. Calc- alkaline rocks are rich in magnesium, calcium oxide, alkali metal and make up the minor part of the crust of the continents. The diverse rock types in the calc- alkaline series include volcanic types such as basalt, andesite, dacite, rhyolite and also their coarse- grained intrusive equivalents gabbro, diorite, granodiorite and granite. (Figure 6&7).

Table 1. Whole rock geochemical analysis of igneous rocks in the study area.

Sample.no	*SiO2*	*TiO2*	*Al2O3*	*Fe2O3*	*MnO*	*MgO*	*CaO*	*Na2O*	*K2O*	*P2O5*	*LOI*
KMT-1	63.88	0.16	14.8	1.76	0.05	0.55	1.43	4.93	4.12	0.06	0
KMT-2	63.12	0.08	13.4	1.3	0.03	0.93	0.927	4.63	4.43	0.03	0
KMT-3	59.54	0.08	12.7	1.23	0.03	0.31	0.97	4.22	4.49	0.02	0
KMT-4	68.86	0.09	14.8	1.32	0.03	0.3	1.09	4.75	4.95	0.03	0
KMT-5	57.75	0.15	13.3	1.68	0.05	0.49	1.33	4.44	3.85	0.06	0
KMT-6	56.49	0.44	14.7	3.33	0.11	0.89	1.91	4.61	4.28	0.18	0
KMT-7	52.13	0.42	14.7	10.13	0.19	8.13	5.42	1.62	6.11	0.33	0
KMT-8	51.11	0.40	14.5	10.1	0.18	8.05	5.44	1.58	5.97	0.32	0
KMT-9	55.65	0.41	13.6	3.82	0.03	6.4	0.72	1.28	4.1	0.13	0
KMT-10	75.19	0.39	11.89	3.59	0.09	1.45	1.90	2.17	2.13	0.14	0.16
KMT-11	*77.85*	*0.06*	*8.33*	*2.53*	*0.00*	*0.46*	*0.81*	*1.59*	*4.26*	*0.01*	*0.17*
KMT-12	*71.43*	*0.15*	*9.33*	*3.15*	*0.03*	*0.74*	*1.84*	*3.15*	*2.05*	*0.05*	*0.15*
KMT-13	*77.3*	*0.14*	*13.63*	*1.31*	*0.01*	*1.5*	*0.03*	*3.17*	*1.13*	*0.04*	*0.97*

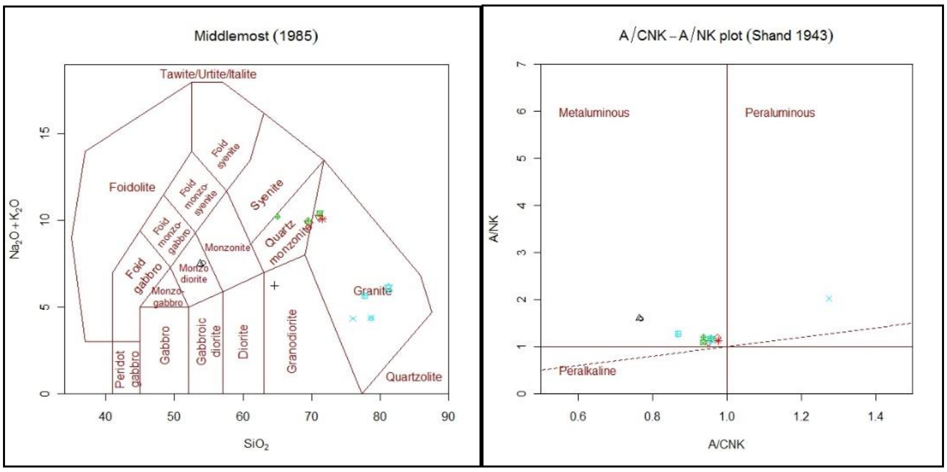

Figure 6. Na_2O+K_2O versus SiO_2 diagram of TAS by Middlemost, 1985, and A/NK (molecular Al_2O_3/ Na_2O+ K_2O) Vs A/CNK (molecular Al_2O_3/ $CaO+Na_2O$+ K_2O) diagram showing the subalkaline and metaluminous character of igneous rock of the study area. (Shank, 1947).

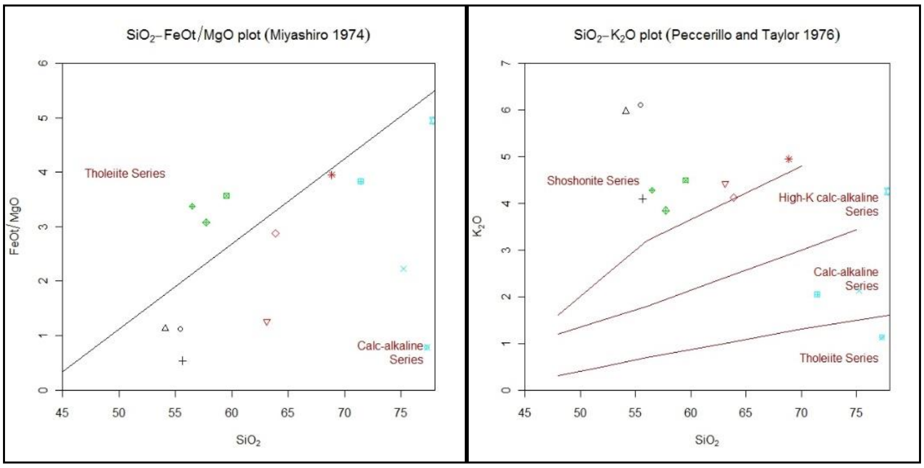

Figure 7. K_2O vs SiO_2 weight percent, the dividing line chosen by Peccerillo and Taylor, 1976.

Fluid Inclusion Microthermometry

Fluid inclusions were studied on samples of gold-bearing quartz vein. In total, six samples were measured in order to examine the different type of inclusion present (CO_2 rich three-phase inclusion and liquid-vapor phase inclusion), morphology, size, liquid-vapour ratio, distribution and origin of inclusions. Microthermometric measurement was conducted.

According to the data collected from various inclusion under microscope, three types of inclusions are notified according to their characteristics (1) CO_2-rich inclusion (2) three phase inclusion and (3) liquid vapour phase (Liquid rich) and liquid vapour phase (vapor rich) inclusion (Figure 4). The fluid inclusion morphology of inclusions occurs either isolated or in clusters, aligned or randomly distributed. The fluid inclusions mostly exist in two phases, liquid and vapour, at room temperature. They vary from <1 to 15 μm in length, exhibiting shapes that range from regular to irregular. Minute elongated fluid inclusion trails (secondary inclusions) arranged along fractures within quartz crystals or cutting across grain boundaries are abundant.

Microtherrmometry: Most of the data reported in this paper were obtained from measurements of inclusions in quartz from the vein quartz. The inclusions reveal two phases at room temperature: liquid H_2O and CO_2 gas. Fluid inclusions from the Au bearing stage are H_2O-CO_2 rich fluids with low salinity <10% NaCl.equiv. The trapping temperature of the ore fluids between 290°C to 380°C at pressure between 120-170MPa (800 to 1800m depth). These homogenization temperatures correspond to CO_2 densities of 0.85 to 0.87 g/cm^3 (Roedder et al., 1997). Total homogenisation temperatures (Th) of the aqueous-carbonic inclusions from Kyathitmyaung gold prospectis in the range from 270 to 395°C with low salinities of 2-10 wt% NaCl equivalent.

Raman Spectroscopy Analysis: Laser Raman tests have been carried out on different types of inclusions as CO_2 vapour, vapour liquid and three phase inclusion which were collected from different auriferous quartz veins of the deposit. The data and results from Raman test indicated that water and carbon dioxide are the main contents of all types of fluid inclusions (Figure 8). Fluids associated with formation of orogenic lode gold deposits are H_2O-CO_2 with low salinities. This composition is consistent with fluids in equilibrium with the host rock and alteration mineral assemblage. Relatively high density H_2O-CO_2 fluid inclusions are characteristic of the orogenic lode gold deposits. (Roedder et al., 1997). Three-phase H_2O-CO_2 fluid inclusions are typical of metamorphic gold deposits but which are almost never found associated with epithermal gold deposits. In addition, Raman spectra showed trace of CH_4 spectra of (v:2917cm-1) and obtained Raman spectra of CO_2 (v1 : 1388 cm-1 and 2v2:1285cm-1) (Figure 8). High content of CO_2 is one characteristic of ore-fluid composition at Kyathitmyaung gold deposit. Figure 8 shows the nature and type of fluid inclusions in Quartz and compositions of fluid inclusions, which CO_2 rich fluid inclusions during Raman Spectrometry Analysis and Raman peak showing CO_2+CH_4 rich in some fluid inclusions from Kyathitmyaung gold deposit.

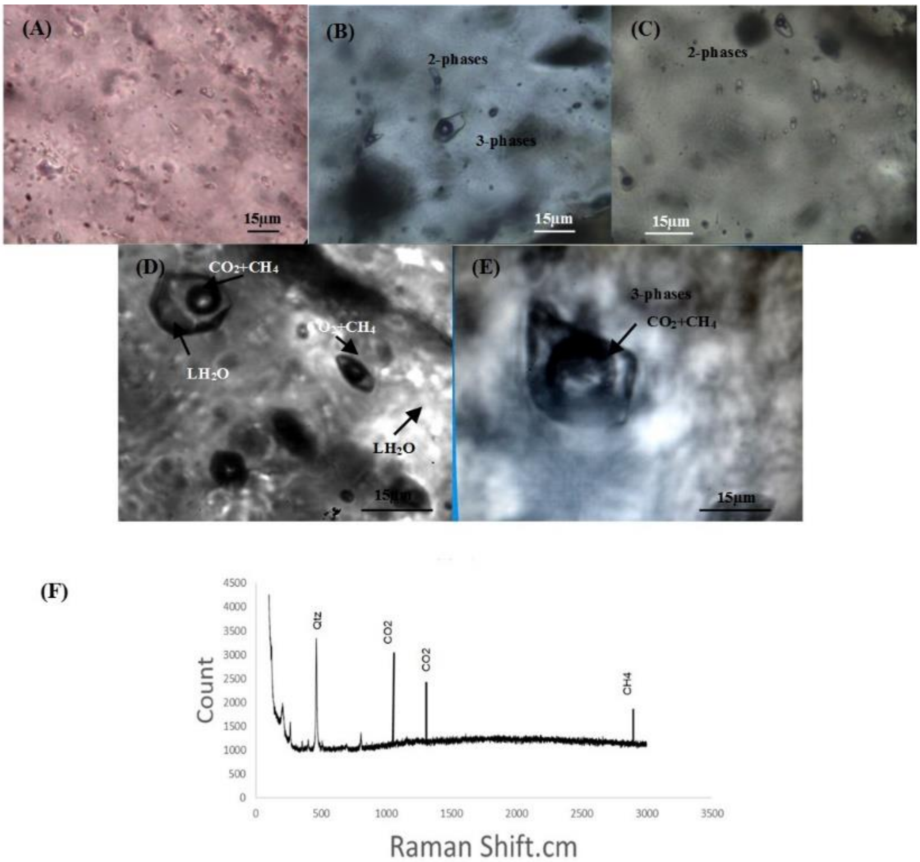

Figure 8. Photomicrographs of (A) nature of fluid inclusions in Quartz, (B,C,D,E) types and compositions of fluid inclusions, (D,E) CO_2 rich fluid inclusions during Raman Spectrometry Analysis, (F) Raman peak showing CO_2+CH_4 rich in some fluid inclusions from Kyathitmyaung gold deposit.

Conclusion

The research area is located at Kyaukkyi Township, Bago Region. Geologically, the area is mainly composed of Mergui Group (Carboniferous metasedimentary rocks with the age of Carboniferous to Permian) and which was intruded by the Mesozoic granitic rocks (diorite and granodiorite). Gold is accompanied with pyrite, arsenopyrite and minor base metal mineralization such as chalcopyrite, galena and sphalerite. According to the ore texture, ore mineral crystallizations have the two stages in the study area. The intense wall rock alteration is silicification, sericitation, kaolinization and chloritization. AAS data shows the potential of gold ranges from 0.01 to 3.34 ppm. According to the interpreted diagram, all granitic rocks in the study are are acid to basic composition and tholeiitic to calc- alkaline rocks. If, alluminium, calcium, sodium and potassium volume is less than 1 and fitted into the metaluminous field. This granitic rocks can be interpreted the I- type granites. The early mineralization stages of the Kyathitmyaung gold prospect evolved from a complex H_2O-CO_2-CH_4 low salinity (<10 wt% NaCl eqv.) fluid. The precipitation of gangue mineral (quartz)is the occurred most probably at 2-4 kbar and 280–396°C from unmixed aqueous-carbonic fluid. The fluid inclusion data of ore-related hydrothermal minerals indicates that the formation of these gold-bearing veins involved dilute, aqueous carbonic fluids that were generated from metamorphic dehydration reactions at deep crustal levels. With respect to the suggested temperatures of quartz precipitation and fluid composition of H_2O-CO_2-CH_4 ratio is more likely a metamorphic source. Moreover, the results direct to a deep crustal source for the ore-forming fluids as mesothermal style deposit. Deposition of Au sulfides has taken placed at the shallow levels can suggest that the mineralization is from magmatic-metamorphic origin. Based on the tectonic setting, nature of mineralization and fluid characteristics, the gold mineralization in the Kyathitmyaung area is consistent with an orogenic style of mesothermal deposit type.

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